Foundations of Special Relativity and the Principle of Conservation of Information

C. Pombo and Th. M. Nieuwenhuizen

Institute for Theoretical Physics, University of Amsterdam,
Valckenierstraat 65, 1018 XE Amsterdam, The Netherlands

The theory of special relativity can be generalized by means of a new principle called Conservation of Information. This allows a derivation of the constancy of the velocity of light with respect to moving frames, and, consequently, of Einstein's special relativity. The analysis is based on a review of the concept of observer. It is put forward that observers are not uniquely defined and that an observational asymmetry, defined by the different ways in which light influences observations, lies at the origin of the non-absolutism of time. This observational difference is a kinematic condition, not an exclusive result for light, implying that non-absolutism of time may have a cause different from the electromagnetic nature of light. The Lorentz transformations are derived and different concepts of the velocity of light, relative to different classes of observers, are considered.

I.   INTRODUCTION

The theory of special relativity is based mainly on three principles. The first is the statement of the rectilinear uniform movement. The second is the constancy of the velocity of light as it was named by Einstein. The third is a generalization of Newtonian dynamics. The two first laws are pure kinematic in their nature. Alone, they can be represented by means of the two well known fundamental Lorentz transformations for time and space [1].

$$t = \frac{t'}{\sqrt{1 - v^2/c^2}}$$

and

$$s = \frac{s'}{\sqrt{1 - v^2/c^2}}.$$

If understood correctly, these expressions alone already have the answer for a question which has been occupying the minds of many physicists and philosophers since Einstein. This is the question about the origin of the constancy of the velocity of light, whether it is due to its electromagnetic nature or not. We will explain, in simple terms, why the answer is certainly not.

In pure classical physics, these transformations should be replaced by the Galilean transformations, which do not involve the velocity of the light. If we assume that t' and s' are sequences of measures of proper time and proper length, which are just names for the classical measures, we are also assuming that these measures do not depend on light, but on classical relations and standard units of measurements. Then the equations state that the other two sets of measures, s and t, depend on the velocity of the light. Consequently, there are different classes of measures, the ones depending on the velocity of the light and the others which do not depend, implying different ways of observing. And, if this is the case, there emerges the question of why certain observations depend on the velocity of the light and others do not.

Before to focus on this question, two aspects of these relations deserve careful attention. Firstly, they only involve the velocity of what, in separated words, is said to be the velocity of the light. Because velocity is a pure kinematic concept, in that concept of velocity c there is no indication about what moves. In general, velocity of wave is defined by means of wavelength and time, as $v_w = n(t)\lambda/t$, where $n(t)$ is the number of waves considered in an interval t. Since in this expression there is no signal of electromagnetism, we can assume that, in those expressions of Lorentz transformations, the velocity c is not necessarily the velocity of an electromagnetic wave.

Measures of spatial distance are based on systems of reference and Galilean relativity teaches us that expressions of trajectories are relative to the velocity of the reference systems. This does not involve change of unit or transformation of coordinates, which can be fixed with respect to all systems of reference. Comparison between measures also presupposes a common units. But when distances become dependent on an extra parameter such as a velocity, there can be a change of unit, specified by the movement of a certain entity.

If this is not the case, the unit is fixed, then the new

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[1] The question why these laws can be expressed by means of transformations can be easily explained. Laws are statements for classes of phenomena, not for individual events. Then, considered as a set of measures, a relation connecting the sets can be interpreted as a transformation. But it can also be interpreted as the description of a specific event, with respect to an arbitrary system of reference. In this way, a transformation also represents the arbitrarily or generality of the event. The first relation involving times, comes from the assumption of the constancy of the velocity of the light in the expression of the relative velocity, as it is usually done. From $c^2t^2 - v^2t^2 = w^2t^2$, setting $wt = ct'$, we get the first transformation. The second one is just obtained by multiplying both sides by v and substituting $s = vt$ and $s' = -vt'$. These correspondences can be found in many text books and articles. See references [20, 21, 22].

parameter represents a new object of reference and there emerges the question of the uniqueness of the event, when described by different observers. This is the second aspect to notice, brought by the transformations above. If one observer describes an event including a certain entity, while the other point of view does not, in which sense can we say that the different points of view are about a unique event? In this case, the observations are qualitatively different, so we must speak about classes of observers and we cannot define uniqueness, unless we define a new class of observers, integrating both classes already present, unifying them. In this case, those transformations simply say that the uniqueness of events, with respect to different classes of systems of reference, or observers, does not occur at the same time. Considering a specific event, observations not depending on the travel of the light happen during a certain interval of time, while observations depending on light happen during another interval of time. The different classes of observation happen with different time durations.

These two aspects of the transformations only point to the optical nature of light, independent of its electromagnetic nature. As an optical entity, light can be a means for observations of distant events. In principle, this does not depend on dynamical aspects of the events and, consequently, of their electromagnetic features. Originally, the rate v/c, which rules the fundamental conversion of measures, is only a signal of conversion, an observational term, not representing any term of interaction between the systems of reference involved. It does not take in account the physical nature of what is being transfered between the observers. In conclusion, we do not have any *a priori* reason to assume that the fundamental Lorentz transformations of space and time have an electromagnetic origin. This is the reason why Einstein never derived his special relativity from anything else but postulated it. The choice of the formulation, if by means of the two laws or by means of two fundamental Lorentz transformations, is irrelevant for us since they are equivalent to each other. The fact that special relativity and Maxwell's electromagnetism are both based on the non-absolutism of time only shows that Maxwell's theory is a relativistic theory.

In order to derive special relativity from another basis, Einstein had to explain the origin of the non-absolutism of time, independent of the constancy of the velocity of the light itself. This was his intention, when he discussed the relativism of the simultaneity in his book 'Relativity' [1]. There, Einstein introduces the question of simultaneity by means of an experiment which became known in the literature as the 'train/embankment experiment'. The experiment involves two beings named observers, one localized in the train and the other on the embankment. The train moves and these beings are reached by light coming from two separated but simultaneous lightnings striking the train. Einstein assumes that he explains the relativity of the simultaneity by means of analyzing the way in which light reaches the bodies of the physical persons he considers as observers. However, a careful analysis of his experiment, shows that several of Einstein's remarks about what these beings observe, are impossible to occur to physical observers in the conditions he describes.

The main problem in Einstein's discussion was the hypothetical localization of the observers, as argument for what they observe. This idea of localization generates serious misunderstandings because it suggests to the readers that our ways of thinking in physics can be a result of the places in which our bodies are settled. After Einstein, the vast literature concerning special relativity adopted the localization of observers as a didactic method[2]. The localization of an observer as a physical person is supposed to explain why a local measure can be known by a specific person and not by a second one supposed to be far from the first. In this explanatory context, a measure can be known from a register without the need of transmission of light, because the person, who is the one who knows, is so near the register that can see, touch or hear it without delay in time or any kind of distortion due to relative movement. Another person cannot perceive the same signal, at the same time, because depends on reception of light for this. The problem in this argument is that to perceive is not the same as to know. To know, which in the context of physics is the same as to observe, is more than to measure or count. To know accounts for what is done or thought about the measures. A pure measure is always an arithmetic element, without a physical context and, consequently, it is not a physical observation. One single set of measures can give rise to more than one physical concept and this is the main reason why the localization of measures does not give rise to specific observations. Two physical persons, in different places, can think differently about the same set of measures but a single person can interpret the same numbers in different ways. Consequently, it is not localization of persons what produces different observations. In this way, a single person can play as two different observes and, consequently, an observer is not a physical person. So, localization of persons is far from explaining the fundamental point of relativity. As far as we know, no analysis was carried out to elucidate the question of the non-absolutism of time as an observational fact. In the literature, special relativity starts from the non-absolutism as a postulate, otherwise the constancy of the velocity of the light is the starting point.

Localization is not a condition of physical observers, but it can be a condition of other kinds of observation. Physical observations are physical statements and depend on systems of reference, not on interaction between bodies of persons and events, as it is the case for perceptions. The latter are observations of the senses, not

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[2] There is a vast literature concerning special relativity. We cite a few standard textbooks, in the end of the section of references.

of physical events outside. In both cases of observation, physical and perceptual, reception of light can be a necessary element and these observers belong to the class of the receivers of light. But, because reception of light takes for granted light which is locally registered, receivers of light cannot describe light waves or light rays which are in the space around the register. This is the reason why this class of observers never describes or observes light in space, but only far events which emit or reflect light. To register and to observe are not the same process, observations can happen by means of light or without light and, while reception of light is local, observation is not. This is why localization of observers does not play role on observations.

In the train-embankment experiment, Einstein did not discriminate between classes of observers, because considering that something more than registration was necessary for observations, it could generate doubt about the nature of the observers, if they actually could be replaced by registers and machines. However, registration alone does not give rise to associations between local measures and nonlocal ones, such as trajectories that are associations between the sequence of local cycles of a clock and far distances. Einstein interpreted local reception of light from distant sources as the knowledge of distant source, without realizing that this only can happen for receivers of light. In this way he assumed a direct correspondence between non simultaneity of local reception of light from two distant sources and non simultaneity of the separated emissions at the sources. But this does not happen if one can observe the travel of the light. In his explanations, he went further by considering vision as element of physical observation, stating that his observers could see rays of light. This assumption is a serious mistake, frequently found in the literature, and it only led to contradictions in his exposition. Light is a medium for vision, never an object of sight. Observers can observe light but not by means of reception of light and consequently not by means of sight.

There are different classes of observers in special relativity and this is the first reason for the non absolutism of time. For instance, there are classical, semi-classical, and non-classical observers, all coexisting in the relativistic experience. Relativistic phenomena are integrations of different kinds of phenomena. This is the same as to say that relativistic observations are integrations of different kinds of observation. To be more precise, a unique atomic object emitting light can be considered as a clock or as an indirect means for observation of material processes or movement of bodies, but it can also be taken as an objective material event, independently of the light which it produces. This means that different messages arise from the same set of numbers of cycles of light. The point to be kept in mind is that if light is a means for observation, it cannot be objectively observed considering a single observer, these two roles are antagonist. It is based on this kind of antagonism that different classes of observer have to be defined.

So, it is not because observers are inside or outside the train that they find classical, non-classical or relativistic results. All these misunderstandings about observers, sensors, perceivers, thinkers and experimenters, only show the necessity of a fundamental revision of the concept of observer. Observers are beings in transformation, inside a developing physics. It is not only in relativity that we find observational changes. Physics developed in the direction of more sophisticated theories, but the physical world became somehow detached from the experience of the physical world, expelling the observer. It is a common saying in the physical environment that physical phenomena can be derived from abstractions, such as Minkowski space, wave functions etc. These abstractions are not considered to be physical phenomena and, consequently, they are not physical entities. Not worrying with the fact that, not being physical, they still must have a nature, many scholars do not realize that in this way they can be deriving physical results from the metaphysical world. So, if we do not find the observers of the physical worlds, it becomes very difficult to explain physical phenomena. Without physical observers the world has no physical meaning.

The organization of this paper is as follows. Section II is about the several concepts of observer and Einstein experiment. Section II-A discusses different kinds of observation comparing perception with physical observation. Section II-B recalls the setup of the train/embankment experiment and its main points concerning the present work.

Section III is about the observations of Einstein experiment. Subsection III-A is about the basic observational concepts. Subsection III-B describes the conditions of the observer who, in the opinion of Einstein, should be inside the train. Subsection III-C describes the observations of a person who was considered by Einstein as being on the embankment.

Section IV is about observation depending on reception of waves. Subsection IV-A discusses common points in observations depending on reception of material waves and on reception of light waves. Subsection IV-B shows that different kinds of observation correspond to different concepts of velocity for light. Subsection IV-C explains how different measures of time can arise for different observers.

Section V is about relativistic observation. Subsection V-A comments on the origins of the equivalence of Galileo. Subsection V-B introduces a generalization for the Galileo equivalence. Subsection V-C introduces a principle of conservation of information. Subsection V-D finally presents the derivation of the constancy of the velocity of the light.

In the conclusion, we add a with few comments about the relativistic observer.

And in the Appendix we present a model of observer, based on the ideas of Jung, Weyl and Carnap, which underlies our reasoning.

II. ABOUT OBSERVERS, RECEIVERS OF LIGHT AND PERCEIVERS IN THE EXPERIMENT OF EINSTEIN.

A. The various concepts of observer

Observation is a process of description. There are many kinds of observation and consequently of phenomenon. Physical observers correspond to physical phenomena, and are expressions of specific physical languages with their own concepts and expressions. Psychological observers also exists and they are responsible for the psychological phenomena, described by means of their specific language too. Perception, or observation of the senses, is not physical phenomenon but psychological event, although it depends on localization of observers as physical bodies. Because a sensorial experience originates from the interaction of a being with the environment, perception depends on the spatial localization of the observer's body. Vision and hearing, among many others, are modalities of perception. And, because two physical persons are not identical, and neither can be at the same place at the same time, perceptions are individual and subjective experiences.

Vision, which is one between the several modalities of perception, is the result of a combination of many processes of different nature. It is a psychological phenomenon but it also has a physical base. Real vision only happens with the physical stimulation of the retina and consecutive processes in the body of the perceiver. The retina is a structure of cells with a layer of photo-receptor cells. From the physical point of view, we may assume that space is filled with a non-homogeneous spatial and temporal distribution of matter, which produces, absorbs and reflects radiation. In this picture we also can consider the existence an open and finite surface layer (which can be a retina) of a certain body inside the space, also considering radiation constantly reaching the surface. Light reaching this physical retina produces a distribution of energy inside the material of the retina, corresponding to a radiation pattern reaching the surface. This superficial pattern is due to the luminosity which results from the distribution of sources outside. Then, there is a correspondence between the energetic distribution inside and the distribution of matter outside. The resulting processes inside the material retina are propagated to the interior of the body and these processes all depend on the kind of matter and material structure of the first layer and interior of the body.

If the physical outside can now be considered only one, the retina has two functions. In sensorial terms, the retina becomes a superficial distribution of brightness. While luminosity is purely a physical concept, brightness is a sensorial experience. Psychophysical measurements, relating reports of people to physically controlled stimuli, account for relations between brightness and luminosity. The perceptual world of vision starts with distribution of brightness and ends with distribution of bodies in space.

But these are not physical bodies or a physical space. The contrast in brightness is one between the sensorial and non-sensorial elements forming the perception of individual bodies and emptiness that is interpreted as bodies in space.

In spite of the fact that perception of space is not only a visual acquisition but has other origins, visual perception always includes space and it is not yet completely understood. With spatial perception, a geometrical configuration emerges and the experience of a distant object occurs, which actually does not coincide with the physical picture of the facts. It is well known from psychophysical experiments that perception and physical observation do not share a common geometry. This fact was firstly realized by Rene Descartes, who was the founder of the science of psychology. Before him, psychological phenomena were usually assumed to be manifestations of a religious soul. He inaugurated a revolutionary approach of the psychological phenomenon, by stating that soul manifestations and physiological processes were correlated. Correlations of this type form the science of psychophysics and, until nowadays, this empirical science is the only available tool to study the neuro-psychological correlations. The question of the space can also be studied by means of the psychophysical approach and many research had been done on the issue of the perceptual geometry [2].

Although the notion of space, as emptiness, seems to be a single and innate idea, perceptual space and physical space are not the same concept. Then, we can assume that these two spaces, the perceptual and the physical, are separated from the beginning. This means that when we say that we see the outside, we are only speaking about the perceptual outside which, in the end, is a representation of internal processes of our body. The physical outside can be known but it cannot be seen.

Vision is only one among the several kinds of observation based on reception of light. The retina is just a material register, like all physical registers and, due to this fact, it shares with all registers the property of not being able to account for processes which are not registered. Whatever can be registered, only becomes registered by means of the matter of the register. All this gives us the certainty that we are not able to see what is physically outside, as light waves must be, in order to make our vision. The concept of light wave is a pure physical concept and, if we conceived it, it cannot be because someone saw it.

Contrary to perceptions, physical observations are objective experiences in the highest degree. Experiences of a single person do not play any role in physics, what one single person observes is what everybody in all places, even moving with respect to each other, can observe. Therefore it is clear that a physical observer cannot be a person perceiving. To really understand physical observers, it is necessary to know that not everything we know happens to us because of the interaction of our body with the external world. It is not only through

sensations that we know the physical reality, on the contrary [3]. It is a very known fact that we humans, not only are able to experience much beyond our individual circumstances, but we are also able to know aspects of the physical world without the help of experimental proceedings. The history of Knowledge is full of these cases, the ideas of rectilinear uniform movement and the existence of atoms are a few examples.

In the context of Einstein's experiment, the only common point between perceivers and the physical observers, of classical physics, is that both are receivers of light. By definition, a receiver of light is a being that only observes or knows about processes or events producing light, by means of light emitted from them. Receivers cannot observe the light traveling in space, because for this, they would have to receive (or register) light instantaneously from the complete light wave spread and traveling in space. This cannot be, because this would imply that two different kinds of light, one traveling with infinite velocity and another with its usual velocity should be present together. As a consequence of the fact that they do not observe light traveling in space, they do not know that they receive light to observe far events, they only observe these events.

The main difference between a classical observer and a visual observer is in which way distances are defined. In both cases, registration of light is local. In case of visual perception, distances are not necessarily quantified and when it happens, quantification does not mean an objective proceeding. This means that distances are subjective and locally defined. But in the physical case, distances are defined by physical means, independently of reception. And an observation is not a registration but a continuous association between registrations and objective distances, making the physical observation a non-local phenomenon. The objectivity of the distances comes from the physical knowledge of the rectilinear uniform movement, which is an *a priori* element of classical observation. Due to this fact, even for receivers and classical observers within relativity, observation is nonlocal since distance is nonlocal by principle.

But this is not all about physical observers. When light reaches a register, it can be interpreted as a reception of light if one accounts for the fact that a wave of light was emitted from a source, reaching the register. But it can also be interpreted as a material process of a distant

object, when one does not account for the travel of the light wave. The first case clearly implies the existence of another kind of observer, the one who is able to describe the movement of the light wave, without reception.

With the observation emerging from sensation, we have perception, and the perceptual concept of brightness. In the physical domain a new kinematic quantity, characterizing reception, must be defined. This cannot involve the concept of luminosity, which in the end, is a dynamic concept, measuring the effect of the radiation on a surface register. But considering that the retina can register oscillations of brightness, we may consider that in the specific case of measuring numbers, perception and physical observation are coincident. In analogy with the perceptual case, we may assume the concept of physical brightness, represented by the number of waves reaching a detector or retina, as an observational feature of the physical object. In this sense we may say that our body can also act as a physical register, having other means to observe, in the physical sense, the source of light. Otherwise, we cannot be sure that there is indeed a source somewhere else and the sensation of brilliance cannot be taken as objective.

The term "physical brightness" is only an analogy to the perceptual experience of bright, since the spatial localization of persons does not influence the physical observation. From a device receiving light, the number of received waves would be the signal of the existence of the oscillatory object at distance. Brightness here is just a name for what becomes the signal, or representation, of the object. The possibility to connect these two distant realities, does not imply in the physical localization of a person, but implies the existence of a person. Actually, this connection is the mark of the human being: the fact is that we make these connections. Here we do not explain them but only take them for granted. Moreover, we also can avoid them, and it is exactly what we do when we interpret the same data, from the same device, as a pure local event. And it is not a question of our physical presence whether we tell one or another story about the same data.

So, Einstein could also have considered a large crowd spread on the embankment as well as a limited train filled with many beings. The measurements in the embankment and the ones in the train could be known by each and every one, independently of being in the embankment or in the train. Neither was the movement the reason for the observational difference. What actually produced the difference was the way in which data made by light were interpreted in the description of the facts. The physical world, that is, the set of all physical experiences, is not the perceptual world of our daily experiences, the one we can see, smell and touch, as people usually suppose, but the one we know by means of phys-

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[3] We are able to describe objective experiences not produced by any kind of stimulation triggered by the effect of the physical outside on our sensorial organs. With this we are not saying that thoughts can exist without brains. What we say is that there are thoughts, occurring concomitantly with the stimulation of the neural system, which are not originating together with sensation and perception. This is not at all an original assumption, it is well known in neuro psychology. But the main interest of the sciences influenced by the logical positivism, dominating the last century, was to deny the existence of this kind of thought. Special relativity was the main representative of these sciences.

ical observations. Physical observers [4] are not beings to be found inside the physical space, measuring or doing something else. Actually, this observer of the physical literature is just a name given for a special kind of thinking representing a specific collectivity.

B. Einstein's train/embankment experiment

The train/embankment experiment was introduced by Einstein to explain special relativity. In essence, the situation discussed is the following: there is an embankment and at a certain initial moment $t = 0$ the origin O_{train} of a train passes through the origin O_{emb} of the embankment, with a constant velocity v_e. At O_{emb}, there is a source of light. [5]

An observer[6], named $observer-train$, is located in the train and employs its three-dimensional walls, with origin at O_{train}, as his inertial reference frame. Another person, named $observer-emb$, is at the embankment, with origin O_{emb}, using it as his inertial reference frame. It is said that because the velocity of the train approaches the velocity of light, relativistic effects are noticeable, between the two observers, such as discrepancies in measurements of space and time.

But, in his experiment, $observer-train$ is a genuine classical observer, measuring his 'proper time'. Consequently, he cannot know that his time is different from the embankment time and neither can he use the constancy of the velocity of light to know where the moving object is, because this is a condition of special relativity only, not of classical physics. It is important to notice that, in Einstein's exposition, the embankment has no limit in size, the experiment has no limit in time and the embankment clock serves the whole embankment. This means that $observer-emb$, describing all the sequence of positions of the train, uses only one clock. Consequently, for this observer there is no sense in the concept of local time and he has no reason to suspect that inside the train there could be another time, not even if he is able to read off a clock moving with it.

Based on conventional ideas about what observation is[7], we assume that observers only measure distances and intervals of time. Trying to understand this, we assume that we only can be in the conditions of one or another observer. And, because both do not understand each other, we finish not understanding the relativistic reasoning. One of the problems in the exposition of Einstein is that it does not explain the true origin of the non-absolutism of time, that is the observational difference. Because of this, he does not tell us that the relativistic conclusions are only due to the existence of a specific observational entity, the relativistic observer, who defines his own relativistic concepts and whose conclusions are coded in the equations of special relativity.

The non-absolutism of time is the first serious discrepancy introduced by special relativity. Discrepancy means difference or disagreement, also implying comparison or a certain level of equivalence. In our opinion, there are discrepancies in measures of lengths and time, first of all, because the two observers are different and remain different. They do not know the discrepancies and are separated from the beginning. But their measures can be compared by someone else, in other conditions. Time is non absolute only for this third observer.

In our experiment, $observer - train$ measures time from a near clock but depends on reception of light for observing objects at distance. But he cannot observe the light waves he receives. We will show that it corresponds to the situation of a classical observer.

The other observer, supposed to be on the embankment, measures time from a clock at the embankment, observes the movement of the train, the wave of light in the usual three dimensional space, but he does not need reception of light for observation of light. This one is named the "semi-classical" observer.

When the two origins are at rest together, they agree with all their measures of space and time. However, when moving away from each other, these measures do not coincide. In all what follows, we make the hypothesis that light as a wave phenomenon, consists of a series of pulses in space. To simplify matters we consider monochromatic waves only.

III. THE TWO TYPES OF OBSERVER

A. Physical concepts and observational elements

We find in the physical literature, concerning relativity, distinctions in concepts of time such as proper time and relativistic time. The proper time is usually defined as a local measurement of time, not depending on optical means. It is used in this sense that light does not convey information from the clock to the observer. But the so called relativistic measurements, are also measured by a local (in the same sense) clock, usually serving the whole space of the experiment. This is the case for relativistic events inside laboratories. Only one clock on the walls can be used to measure the so called relativistic time. Therefore this distinction, based on distance from

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[4] The expression 'physical observer' does not mean 'observer with physical body' but 'observer of the physical world'.

[5] Though we shall follow Einstein in considering light, our discussion would be easier to follow when speaking about the equivalent case of radio waves, because then the wavelengths exceed the size of human bodies, etc.

[6] We repeat Einstein with the idea of persons as observers otherwise we cannot discuss his experiment. But the reader can always think of many persons describing the same observations

[7] The assumption that to observe is to measure.

the clock to the observer [8], does not give a meaning for proper time.

As we explained before, an observer is not a localized physical person perceiving events and making the measurements, but the one who describes events, by associating data [9]. In general, a phenomenon (an event in development, or just an event) is a continuous succession of happenings in time. A basic feature of physical events is that time is a quantitative reference for them.

Time is quantified by means of units or cycles. Cycle is the common feature of all devices named clock. The cycle is a unit of time, and, for this reason, it is not a spacial entity. However, clocks can have spatial dimensions. A clock is a reference for time, a physical event with the property of being cyclic. There can be several references of time, based on the same unit of time. The observation of a physical event is based on an association between at least two events, one of them being the clock.

A wave is another entity which has a spatial dimension, it cycles and moves in specific directions. The origin of a wave is a cyclic event, independent from the wave itself. As a pure kinematic entity, it combines a spatial dimension to cycles, making moving pulses, transferring cycles from place to place. But the description of a wave is based on the usual references, including a clock, independent of the wave. The pattern of cycles carried by the wave can vary with respect to moving references and can be compared in different places with respect to the same fixed pattern of cycles of the original clock.

Differences in measures of cycles of a wave due to movement, are called the Doppler effect. The difference between the so-called classical Doppler effect and the relativistic Doppler effect lies in the uniqueness of the original pattern of cycles, generating the waves. In the non-relativistic case, the observation of these original cycles does not depend on reception of waves while in the relativistic situation, due to the differentiation in the classes of observers, this original pattern is not observed independently of the reception of waves. Then, an extra correction in the observation of the cycles must be made.

Now we study the different ways of observing the movement of sources and waves and compare them. In our discussion, the origin of the embankment is O_{emb}, where there is also an atomic clock [10], from which electromag-

netic pulses originate. This clock is a cyclic event of the same nature as a lamp

There is also an origin O_{train} inside the train, in which another clock is localized. We also consider that at a certain moment $t = 0$ the point O_{train} of the train coincides with O_{emb} of the embankment.

In other examples with two observers, Einstein assumes that each observer must have a lamp. We consider lamps and clocks as identical objects, concerning their descriptions as cyclic phenomena. Atomic clocks also emit light. A lamp is just a name for speaking about an atomic process emitting light and for this reason it can be used as a clock or vice versa. In our discussion, the cyclicity of these objects is their most relevant observational feature.

Our interest is to study each observer, how he counts cycles or pulses of light, how he interprets them and what light is for him, pointing to the differences in the ways of observing. We are going to put forward that these differences are, in fact, the origin of the non-absolutism of time.

B. The observer in the train

We start by assuming that the observer in the train, $observer - train$, is a classical observer[11]. This just means that he only describes the movement of the embankment, or of an origin in the embankment, with respect to his inertial frame of spatial references at rest with respect to the train. And this is done according to the time measured by his clock inside the train [12]

At this point we just assume that, if this observer were alone, classical physics would be the context of his observations.

About $observer - train$, we state the following conditions:

1-1) He is able to count the number of cycles;

1-2) He uses a clock to measure time;

1-3) He is a classical observer. Consequently, his only expression has the usual shape of a rectilinear uniform trajectory:

$$s_t = v_t t_t \tag{1}$$

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[8] Frequently in the literature, the authors think of observers as beings with bodies, who can measure and disappear when convenient.

[9] In a physical sense, the observer (when considering the body of a human being) can be replaced by a photo camera, even read off by a computer program, as is standardly done in high energy physics. But somewhere down the line, someone has to organize and interpret the data, making up the event by integrating the concepts. This final result is what expresses events such as uniform motion, movement of light, etc.

[10] An atomic clock is a high-stability oscillator based on atomic transitions. The second is standardly defined as the duration of 9,192,631,770 cycles of microwave light absorbed or emitted

by the hyperfine transition of Cesium-133 atoms in their ground state, undisturbed by external fields. In this definition we find the word duration. But 'duration' is not something which exists *per se*, without the physical object which defines it. This is exactly the same as in the case of lengths, in which we must have the physical object to be the standard measure. The length is the object in the same sense that the duration is the object too, in this case the specific atom. So, the word duration makes the definition circular and should be omitted.

[11] We could alternatively assume that observer 2 is a classical observer, with the same results.

[12] What we mean with 'classical observer' cannot be fully explained at this moment. Our method is to state the classical conditions from a non-classical but not yet relativistic context of observation.

where s_t and v_t are the position and velocity of O_{emb}, respectively, with respect to the train, and t_t is the time in the train measured e.g. using his Ce-clock at O_{train}.

C. The observer on the embankment

The second observer, $observer - emb$, describes the cyclic event at the origin of the embankment, the transmission of the waves from there, and their detection in the train. There is a clock at the origin of the embankment. $Observer - emb$ thinks of the embankment as being at rest and also describes the movement of the train. For this observer, light is an objective event, happening concomitantly with the other ones, but it is not a means to observe.

The crucial difference between this observer and the previous one is that he can describe light objectively. This means that he knows where the light wave is in space, without the need of detecting it, to observe it. Experiments may have been done previously, in order to give him the certainty of the velocity of the light with respect to O_{emb}. He can also arrange things in order to know, in advance, all the times and positions from the beginning to the end of the experiment. But, in this experiment, he does not receive (detect) light, from any point and moment of the light trajectory, in order to know where it is. This would be in complete contradiction with the fact that the velocity of light is finite. Light is not and cannot be a means for observing itself, in any case. In this sense, an observer of light is not classical because, in classical experiences, objects at remote distance can be known without considering reception of light, what means without knowing that reception may play a role on measures of time and consequently of distances. A classical observer who receives light is not aware of this condition, and cannot know light as it is. For reasons which will be more clear later, we assume that $observer - emb$ is a semi-classical observer. [13]

2-1) The equation [14]

$$s_e = v_e t_e \qquad (2)$$

is also his form of the movement, where t_e is measured according to next definition, 2-2).

2-2) At O_{emb} there is also a source of light or a lamp. The production of light is described by a frequency that

is defined by an association of a cyclic event with a clock, which is another cyclic event. Frequency is the number of cycles per time. In this way defined, this is not a fixed number but counted as time goes by, therefore it is numerical function of time. Without the two events being compared, neither the number of cycles nor the frequency can be measured.

For $observer - emb$, the original cycles of the atomic event are described by means of a time reference that is also based on production of light from cycles. It is possible to define a generic standard unit of time u_l, by means of the emission of a light pulse according to chosen material conditions and specifications [15],

The original cycles in O_{emb} are atomic transitions with frequency:

$$f^e_{cy,oe} = \frac{N^e_{cy,oe}(t_e)}{t_e}, \qquad (3)$$

where 'cy' stands for 'cycles', oe for origin of the embankment and e for $observer - emb$.

In this equation, $N^e_{cy,oe}(t_e)$ is a pure numerical function, growing linearly with time, describing the number of cycles during an interval of time t_e, as counted by the observer. Because time for us is an ordered succession without end, this expression does not mean just a fixed number but a process of successive numeration, considering a specific interval of time. For $observer - emb$, the original event in O_{emb} is observed by counting cycles and measuring time.

2-3) In principle, the light wave is a spatially extended phenomenon, distinct from the material object producing the pulses. The frequency of the wave is given by

$$f^e_{w,oe} = \frac{N^e_{w,oe}(t_e)}{t_e}, \qquad (4)$$

with subscript w denoting wave.

It just holds that the number of cycles made by the lamp equals the number of cycles of generated light, $N^e_{w,oe}(t_e) = N^e_{cy,oe}(t_e)$, so, in this case, we also have the same frequency:

$$f^e_{w,oe} = f^e_{cy,oe}. \qquad (5)$$

As it is well known, a wave is not completely described by a frequency, but also by the wavelength and the amplitude. While a cyclic phenomenon can be localized in a point, a wave is an extensive object. The distance reached by the wave front in the embankment frame equals

$$r^e_{oe} = c_e t_e \qquad (6)$$

where $c_e = c$ is the velocity of the light wave front with respect to the embankment. This velocity can be given

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[13] A classical observer cannot observe light by definition. An object with the properties of an electromagnetic wave does not obey the Galilean rules and consequently is not classical. It is important to realize that expressions such as 'classical aspects of light' are just ways of speaking, without correspondence with any physical language. But, since we describe the movement of a wave light, we have to assume that we can also observe non-classically. This is what we assume here.

[14] To avoid complications in notation, we assume that $observer - train$ and $observer - emb$ count their lengths and velocities in opposite directions, such that s_t, v_t, s_e and v_e are all positive.

[15] The usual second is defined as described in footnote 10.

by

$$c_e = \frac{N_{cy,oe}^e(t_e)\lambda_e}{t_e},\tag{7}$$

where λ_e is the wavelength. Measuring c_e in the embankment frame, the wavelength can be found from:

$$c_e = f_{w,oe}^e\lambda_e.\tag{8}$$

2-4) We assumed that $Observer-emb$ is not a classical observer but he is also far from supporting a relativistic result: he can observe the relative movement between the wave front and the train. He knows that the velocity of the train is approaching the velocity of transmission of the pulses and that, for this reason, there is a decrease in the frequency of the wave measured at $s_e(t_e)$, given by

$$f_{w,ot}^e = \frac{M_{w,ot}^e(t_e)}{t_e}\tag{9}$$

where $M_{w,ot}^e(t_e)$ is the number of cycles at the origin of the train. $M_{w,ot}^e(t_e)$ and $N_{w,oe}^e(t_e)$ are different numerical functions of t_e, $M_{w,ot}^e(t_e) < N_{w,oe}^e(t_e)$ for every t_e.

$Observer-emb$ can describe the velocity of the wave front relatively to the train by means of the speed

$$c_{ot}^e = c_e - v_e,\tag{10}$$

where c_e is given by equation (8), and v_e velocity of the train. It is important to notice that, for this observer, the relation (10) is an initial condition which does not change with respect to the increasing distances to the train.

And, according to this semi-classical observer, this velocity should be given by

$$c_{ot}^e = f_{w,ot}^e\lambda_e,\tag{11}$$

Substituting equations (9) and (11) in equation (10), we find

$$f_{w,ot}^e = (1 - \frac{v_e}{c_e})f_{w,oe}^e.\tag{12}$$

This frequency, on the left side of the equation, is a concept made by associating two sets of measures, the sequence of times and the sequence of numbers $M_{w,ot}^e(t_e)$. Both sequences happen independently for $observer-emb$. He measures the numbers $M_{w,ot}^e(t_e)$ just by counting cycles arriving at O_{train}. We will show that $f_{w,ot}^e$ is not measured in the train. But we will also show that the sequence of numbers $M_{w,ot}^e(t_e)$ is measured by $observer-train$. The relation between frequencies can be taken from

$$M_{w,ot}^e(t_e) = (1 - \frac{v_e}{c_e})N_{w,oe}^e(t_e).\tag{13}$$

Equation (12) shows that, in spite of observing light, $Observer-emb$ is limited to the clock at the embankment

and he can describe the situation as a normal classical Doppler shift.

This result is not completely classical because a classical observer would not observe light waves. But it is also not relativistic, since it was deduced from a limit in which there is a direct (classical) association between the sequence of cycles $M_{w,ot}^e(t_e)$ and the sequence of cycles of the clock at O_{emb}.

Equation (13) does not depend on equation (12) but derives directly from equation (10). This last relation is integral part of the relativistic description and the origin of factors like $(1 - \frac{v_e}{c_e})$ or $(1 + \frac{v_e}{c_e})$, resulting from relative velocities.

IV. NON-CLASSICAL ANALYSIS

A. Considerations about the two observers

To say that a wave is observed in space and its behavior described, is the same as to say that all regions of the space filled with the undulatory entity are known simultaneously and that this instantaneous information is continuously received, or continuously kept in some way, during the period of observation. This is not only for waves in space but it is true for every extensive body and objects of any kind, such as a distribution of numbers, matter and so on. The word 'simultaneity' is used for this property of global observations, associating two or more regions of events, or even non-spatial events, with one time. It implies a diversity in the associated objects, without implying any condition on the physical nature of these associated objects.

Going back to our situation, there are oscillations being counted in the train. According to $observer-emb$, the frequency of oscillation is given by equation (9). We can reconsider this, picturing the positions of each object in the embankment time and focusing our attention on $observer-train$'s measures and thoughts. It is true that he knows very well the sequence of numbers $M_{w,ot}^e(t_e)$, registered on his apparatus or detector. But he cannot agree on the same relation (12) with $observer-emb$.

Equation (12) is known to be a relation between frequencies of the same object (the wave) observed under different conditions with respect to movement. $Observer-emb$ knows the whole extension of the wave, in the sense explained above and consequently he observes the relative movement between the train and the wave. But $observer-train$ lacks this knowledge of unity of the wave and even of the wave itself, which is so natural for $observer-emb$. This is not due to the nature of the wave, in first place, but to his condition as observer depending on the reception of the waves to observe far objects.

One single wave cannot convey its own pattern of distribution in space. This object we name 'wave' exists between different regions of space and may grow in distance but it does not transport itself between these regions. We

mean that a wave conveys something else, not information about itself, except if its existence is already known independently of detecting its oscillations. In order to know the pattern of distribution of a wave it is necessary to have another wave, or other means of knowledge. And this holds for all kinds of waves.

Exactly like a sailor in a boat, $observer - train$ measures the cycles of the wave at $s_e(t_e)$. But the observation of these cycles in the boat (only up and down) does no inform him about the distribution of waves on the water, far from the boat, already settled at each moment he measures the cycles. Unless he could know the wave distribution on the whole surface of the water, by other means much faster than the wave whose cycles he measures, he cannot know the relative velocity between the boat and the wave and neither the frequency of the original source O_{emb}. In the end, he only knows the number of his local cycles. Equation (12) again does not apply to this case. Implicitly in this equation is the simultaneous knowledge of the different regions of the wave, and consequently their different frequencies, or the relative movement between the wave and the moving reference O_{train}.

But we know that waves on water are very slow in comparison to light. All the problem of observation of the water waves would be solved by reception of electromagnetic waves, giving very fast (practically instantaneous) information about the positions of the source or the traveling pattern of waves on the water and consequently of the velocity of the water wave. In the absence of another wave, the observer in the boat would have only the sequence of cycles of his apparatus to consider. Being used as a clock, the measure of received cycles would represent another notion of time[16].

For the case of electromagnetic waves as the faster medium, exactly the same could happen. The electromagnetic wave is produced by a cyclic atomic event, also used as a clock, and it is the faster known medium which can convey the information of these cycles. The atomic cycles which appear in the measuring apparatus of a moving reference, correspond to the original cycles. But, in the absence of another process, these same cycles must be used as a clock, representing a new unity of time. For someone counting the cycles from his local apparatus and also making from it a reference for measuring time, in the absence of another reference, there appears a difference in the measurement of time as well, with respect to the original measures. The problem is that observers in these situations do not have means of knowing their mutual differences in outcomes of measurements. As soon as the spatial frames of reference separate from each other, they loose information with respect to time and the only means of communication takes time to reach the other.

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[16] This situation applies for organisms such as jelly-fish, if this animal is not capable to use his biological processes as a clock.

These are situations which may happen but they do not fall under the description of equation (12). Observers depending on these moving references, would not have complete information about physical facts, such as the processes which generate the waves. This does not depend on the kind of wave but only on the dependence of the observer on the wave. In the case of light, it would be a lack of knowledge about the atomic processes producing light, independently of its propagation, what actually would mean subjectivity. This is a condition which cannot be accepted.

The difference in time arising from this situation can be expressed by a proportionality between the two times. But these different measures of time do not necessarily mean an independence of the references, in the sense of a genuine new dimension of time, to be named non-absolutism of time. We must reserve this term 'non-absolutism' for a situation in which we can be sure about the objectivity of both observations, what is not yet the case of the situations above described. The fact that moving references exist, with speed comparable to the speed of light, requires a solution for the problem of objectivity.

B. The various concepts of velocity of light

In the previous analysis there was no remark about what $observer - train$ knows about the train itself, which remains the same entity as time goes by. Since the train is a material object, we have to assume that O_{train} consists of atoms. In principle, this system of atoms does not interact with O_{emb}, neither is it influenced by the existence of the embankment in any way. Emitting light, these atoms in transition also form a cyclic object. We can assume that, with respect to this inertial system, the light emitted from O_{train} moves away from it with velocity c_t.

Now, to avoid misunderstandings, we recall all possible velocities of the waves until now involved in the discussion. In our new notation, the inferior indices represent the origin and the reference of the velocity of wave, respectively. The superior index refers to the observer. We have:

$c_{oe,oe}^e = c_e$, the velocity of the light emitted from O_{emb}, relative to O_{emb}, according to $observer - emb$.

$c_{oe,ot}^e = c_e - v_e$, the velocity of the wave emitted from O_{emb}, relative to the train, according to $observer - emb$;

$c_{ot,ot}^e = c_t$, the velocity of the wave emitted from O_{train}, relative to O_{train}, according to $observer - emb$.

$c_{ot,oe}^e = c_t + v_e$, the velocity of the wave emitted from O_{train}, relative to the embankment, according to $observer - emb$.

The fact that O_{train} is a cyclic event can be known by $observer - train$. And, for what matters, we do not need to consider extra Cesium atoms coupled to O_{train}, because the relation between the cycles of both would be fixed from the beginning and it would not add extra

information about the cyclic state and the movement of O_{emb}, for $observer - train$. We just consider O_{train} as a material sample, identical in all senses to O_{emb}, not influenced by the light wave from O_{emb}. This implies that $observer - train$ can share with $observer - emb$ the same number $N_{cy,oe}^e(t_e)$, when observing O_{train}.

According to $observer - emb$, light from O_{emb} reaches the position $s_e(t_e)$ of the train with velocity $c_{oe,ot}^e = c_e - v_e$ and light produced in the train moves with velocity $c_{ot,ot}^e = c_t + v_e$, with respect to O_{emb}. That these light waves produced in the train may leave it with velocity $c_t = c_e$, with respect to the train, is not the point of our discussion. We assumed an O_{train} physically identical to O_{emb}, in all senses. The real point of our discussion is to understand the relativistic claim, which prohibits the existence of relative velocities of light with respect to moving detectors or sources. Special relativity does not say anything about the reason why the value of the velocity of the light in $vacuum$, with respect to its source at rest, is $c = 299,792,458 meters per second$. Consequently, we must assume that $c_e = c_t = c$, since these are the concepts of velocity, defined with respect to their corresponding sources at rest. Instead, the theory says that light from O_{emb} reaches the train with velocity c_e and the light from the train, which in principle should be independent from the one made at O_{emb}, also leaves it with velocity c_e, with respect to O_{emb}. According to the axioms of special relativity, the concepts of relative velocity of light in $vacuum$, here represented by $c_{oe,ot}^e$ and $c_{ot,oe}^e$, do not exist and, consequently, $observer - emb$ does not exist or is mistaken.

Usually, people interpret the facts as if $observer - train$ could observe light arriving from O_{emb} with velocity c_e, but, according to our interpretation, it is not $observer - train$ who arrives at such a conclusions, and neither is $observer - emb$ mistaken. Because $observer - train$ is not an observer of light, his registration of the wave coming from O_{emb} has not the meaning of the arrival of a wave but it has another interpretation. And in the case of $observer - emb$, we must consider the fact that without considering a registration (or reception) of the wave at the train, there is no meaningful relation between the movement of the wave and the movement of O_{train} which could justify a change in its velocity. For $observer - emb$ alone, the increasing difference between the positions of the wave front and O_{train} suffices for an observation of a relative velocity between them. There cannot be a transformation in the velocity of the wave inside the embankment, only due to the fact that it shares the space with a moving body, with which light does not even interact. Then, in our opinion, $observer - emb$ is free to keep his way of thinking. Something else must happen, and we focus on the meaning of this light for $observer - train$.

With these same waves arriving at the position of the train, another kind of observation can happen. Because a wave can be broken in independent pieces of information, considering its features separately, they can be combined differently, showing something completely diverse. We need to understand what is the meaning of the arriving light for $observer - train$.

From one point of view, we know that light reaches O_{train}, but from another this is not necessarily the case. For $Observer - train$, who knows nothing about the spacial existence of the wave, what is out there is a bright O_{emb}. This is a conclusion which we take only by analyzing our own ways of observing, as classical beings, and comparing them with the situation here present. When observing, we do not say that light is in between. If we drown in the condition of the classical observer, we have to conclude, liking or not, that light waves disappear as such between O_{emb} and O_{train}. [17]

In place of this light which disappears, another concept of light must emerge, and this is in fact what happens with the appearance of a cycling feature in the object. Reception of waves has a meaning by itself introducing a physical correlate of brightness, the kinematic brightness, which in this case, does not depend on the characteristics of the wave, but only of the number of waves, as explained in the introduction. And, for the receiver, the number of received waves is a feature attached to the objects at distance, re placing the absent wave. Here, this concept only belongs to receivers of light, not to observers of light. Reception generates a new concept of body, the cyclically shining body, defining the receiver of light. What we mean with reception of light is not a process independent from the observation, or causing observation. Reception is a process which happens together with the corresponding observation, furnishing part of the features of the observation. This cyclicity of the body, coming with reception, is not a 'thing' but a process, a body event, having the duration of the observed event. So, reception is a physical process and a physical concept, involving physical elements, as every physical event, but it is not described by the receiver, who only gets a new concept of body from it.

The 'brightness' has no physical relation or interaction with the cyclic O_{train}, which is a reference for observing the object O_{emb}. It is by means of counting cycles of O_{train} and combining it with the reception of waves from O_{emb}, that $observer - train$ observes the movement of the body, which now becomes more than the simple kinematic object from the pure classical physics. As we know from our own experience, if we think as classical observers, the final observation could be just the continuous trajectory of a cyclically shining object, without any physical medium other than the empty space between the points of the trajectory and the origin of the system of reference. A pure classical body could also be described as moving object only, without necessity of any brightness. But here this feature is the new insight introduced

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[17] Until now, the expression "bright object" could be exchanged by "sounding object, " considering material waves instead of light. We discuss the difference later.

by an observer receiver of light, before the classical limit. His situation is not yet classical, which is a particular case of receiver of light resulting from additional conditions on the process of reception.

As we can notice, light can actually have different meanings for different types of observer. While one describes the wave light, the other, by means of the same light, observes a bright body, which is a completely different concept. For $observer - train$, light, as a wave, is beyond observation. Consequently, for this observer, light does not cross O_{train} because it never enters his observational space, staying there with the body as an integral feature of it. In this way, the disappearance of one entity is partially compensated by the emergence of another one. It is not completely compensated, because brightness is local and the wave is not. Then, something is still lacking and we have to find the light which arrives and leaves O_{train} with the velocity c. Until now, what we know for sure is that if this light actually exists, obeying the relativistic claims, it can only be observation of someone else.

C. The two measures of time

Let us recall some aspects of $observer - emb$'s observations. Equation (13) relates two varying quantities, which are numbers of occurrences or events, by means of a constant. The number of occurrences and relations between such numbers can be physical observations, in the same sense that relations between time, lengths, velocities and other quantities can be considered. Defining $\beta_e = v_e/c_e$, we rewrite equation (13) as:

$$M_{w,ot}^e(t_e) = (1 - \beta_e)N_{w,oe}^e(t_e). \qquad (14)$$

We read in this equation that the relation between the two varying quantities, is valid for each and every time. There is no specifications about the kind of the event whose number is growing in time, neither an indication of a wave spread in space, there is only number of cycles [18]. The name cycle here is used in the sense that the occurrences are identical to each other. This is implicit in the numerical description. Then, we can imagine figuratively the whole phenomenon, as a conjunction of two 'closed' distributions of spots, moving between themselves and keeping increasing in number. In the observational context of $observer - emb$, the physical nature of these spots is only specified by their number. This is a clear case in which counting is a physical description and number a physical concept. And we must understand this fact directly from reading the statement of equation (14), not from external arguments.

Physical observations are expressions of the physical reality only, not explanations about causes of phenomena. Kinematics suffices for the description and this is the reason why dynamical quantities, related to interactions, and explanatory arguments are absent from observations. The kinematics here involves not only numbers but temporal conjunction of numbers. The existence of the number of occurrences without an indication of the physical nature of these occurrences, is very common in physical descriptions. [19]

Now, forgetting $observer - emb$, we think as $observer - train$ observing O_{emb}, with respect to the train, which has its own independent source of light O_{train} at the origin of his reference system. O_{emb} is observed to move away from it, as it happened for the previous observer. The difference now is that $observer - train$ observers the cyclic emissions from O_{emb}, but at the place of O_{emb} by means of reception at O_{train}, while $observer - emb$ did not depend on local reception. This is a condition of receivers of light and it implies that the number of cycles of O_{emb}, counted by $observer - train$ cannot be the number of cycles of O_{emb} corresponding to time t_e.

Local reception has a proper meaning, which does not imply the existence of someone in the train or with particles, as we usually read on the texts. The meaning appears with observational statements, when we make associations of far distances with local registers, when light takes time to reach the register. While building these associations we make the meaning, without being specifically in the place of the register. Since light actually travels with finite velocity from O_{emb} to O_{train}, this takes time and what can be counted as cycles of O_{emb} at O_{train}, only can be a previous amount of the cycles, considering the time t_e. This is the meaning of the quantity $M_{w,ot}^t(t_t)$, instead of $M_{w,ot}^e(t_e)$, in the observational context of $observer - train$. Now, the cyclic state of the object, which is a material process, is measured by means of light and it fixes, objectively, the time of the receiver. The number of waves from O_{emb} counted at O_{train} is the same for both observers, as we already said in the section IV-B, but this unique number has different meanings, corresponding to the different observers.

We can write a similar relation, for $observer - train$,

$$M_{w,ot}^t(t_t) = (1 - \beta_t)N_{cy,ot}^t(t_t), \qquad (15)$$

where

$$N_{cy,ot}^t(t_t) = N_{cy,oe}^e(t_e). \qquad (16)$$

With the introduction of this correction, we can also

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[18] For $observer - emb$, the existence of the wave is stated independently by means of equations (8) and (11), in subsection III-C.

[19] The distribution function of events, extensively used in physics of many-body system, is another example of a numerical concept in physics.

assume that there is a certain factor γ such that

$$t_e = \gamma t_t. \tag{17}$$

For both observations, considering both observers, the physical existence of those numbers of cycles is not to be explained as a result of any kind of interaction. The pictorial spots can also be thought as effects of the passage of an undulatory medium, without considering interaction between a register and the medium. We assume that this is not a physical effect but just an observational effect, in the sense that no interaction is involved which could make of γ a function of time. This is an argument to consider γ as a constant.

This factor γ is the mark of the observational difference. The introduction of this temporal difference, brings again the question of the objectivity. But, partially, it is solved with the assumption that at O_{train} there is an independent source of light. The other aspect of the problem involves the observation of the movement and consequently of the velocity, for $observer - train$. This problem has to be solved by shaping the final trajectory of O_{emb} for $observer - train$ and comparing it with the trajectory of O_{train} for $observer - emb$. In other words, the solution of this problem depends on conditions in which the receiver becomes a classical observer.

Until now we find that the origin of the time difference is not in different clocks but it is in the different ways of observing. In principle, this would still hold if we exchange the shining object by a sounding object.

V. SPECIAL RELATIVITY

A.   Relativistic arguments

It is interesting to notice that the classical and semi-classical regimes of observation, of section III are never subjective or wrong. The classical observation, equation (1), $s_t = v_t t_t$, is objective and correct in all senses. It is so that, for $t_t = t_e$ in quantity, it agrees completely with equation (2), $s_e = v_e t_e$, from $Observer - emb$ language. And nobody can affirm that $Observer - emb$ is wrong, by defining the relative velocity of equation (10), $c_{ot}^e = c_e - v_e$. For every t_e there is actually a difference between the position of the wave front and the position of the train such that equation (10) can be assumed as valid.

The problem is that equation (10) does not necessarily imply equation (12), which describes a rate of emission of a wave light, considering a certain position. Equation (10) and equation (11) are independent equations. Rigorously, the relative velocity of equation (10) and the velocity of equation (11), $c_{ot}^e = f_{w,ot}^e \lambda_e$, are not the same physical concept. Inside the limited context of $Observer - emb$, this fact is not explicit.

Equation (11) does not hold for the receiver because his measure of time is another and consequently the frequency is not the same. Therefore there must be a general equation, instead of equation (12), that integrates

both observers. About a comparison between the two observations, it is also interesting to notice that the observations of $observer - train$ are not under the observational domain of $observer - emb$. A comparison implies the knowledge of invariant quantities by means of which the two observations can be related. Until now, equations (14) and (15) are completely independent. Since we do not know the quantity $M_{w,ot}^t(t_t)$, we also do not know t_t.

B.   Postulate I: Generalization of Galilean equivalence.

Now, we recall that $c_t = c_e$, because these are the velocities of the light defined with respect to the corresponding sources at rest.

We also recall that special relativity is based on the assumption of the conservation of the rectilinear uniform movement. But it is important to notice that, in general, reception of light does not imply in the conservation of the relative velocity, between O_{emb} and O_{train}, given by $v_t = v_e$. So, here, we first assume that

$$M_{w,ot}^t(t_t) = M_{w,ot}^e(t_e). \tag{18}$$

This expresses the conservation of the number of cycles counted at O_{train}, for both observers. Then, using equations (15) and (16), we find

$$\beta_t = \frac{v_t}{c_t} = \frac{v_e}{c_e} = \beta_e. \tag{19}$$

We can substitute these results in equation (14), to obtain

$$M_{w,ot}^t(t_t) = (1 - \beta_e) N_{w,oe}^e(t_e). \tag{20}$$

This equation, which relates explicitly the two observers, is the fundamental form for the generalization of Galilean equivalence, for different observers. It relates the number of wave cycles which vary in time, between moving objects, for different observers, in an unique observational experience.

We can divide both sides of equation (20) by t_e finding:

$$\frac{M_{w,ot}^t(t_t)}{t_t} = \gamma(1 - \beta_e) \frac{N_{w,oe}^e(t_e)}{t_e}. \tag{21}$$

Now we have a relation between the two separated frequencies in space, not depending on time.

$$f_{w,ot}^t = \gamma(1 - \beta_e) f_{w,oe}^e, \tag{22}$$

where the left side of this equation is the frequency of cycles of O_{emb}, for $observer - train$. And now we can discuss the other relation of $observer - train$ with the original source O_{emb}.

C. Postulate II: Conservation of information.

The second postulate is about the classical observer as a limit case of receiver. In classical physics, there is no loss of information concerning material processes.

In our situation, the formation of the cycles at O_{emb}, originating the waves out of it, are observed according to the sequence $N^e_{cy,oe}(t_e) = n t_e / sec$, for n a certain fixed number. This expression must be conserved, with respect to both observers, in their respective observational times. This condition is named conservation of information about material facts. As usual, information is defined as a numerical function of the object, as introduced by Claude Shannon, in the physical literature. [20]. Now the object 'material system', detached from its trajectory, is only defined as number of cycle. So, this is just an application or use of the usual concept of information in the conditions of the phenomenon we discuss [3].

Now we may consider that, in the point of view of $observer - train$, a register of waves at O_{train} can also be considered as a source at rest. The embankment has no limit in length and this permits to consider a point O'_{emb} approaching O_{train} with velocity v_e, (in both points of view), according to the arguments of the previous section V-B. Then, at this point on the embankment, it is possible to define a quantity given by

$$M^t_{w,o'e}(t_t) = (1 + \beta_e) M^t_{w,ot}(t_t). \tag{23}$$

As in equation (15), there is no difference in time since we are in the context of $observer - train$.

However, in the relativistic context, we can relate the two observers, respecting the observational quantities. We can substitute the expression of $M^t_{w,ot}(t_t)$, given by equation (20), yielding

$$M^t_{w,o'e}(t_t) = (1 + \beta_e)(1 - \beta_e) N^e_{w,oe}(t_e). \tag{24}$$

Knowing that all these numerical functions are linear functions of time, we have

$$N^e_{w,oe}(t_e) = \gamma N^e_{w,oe}(t_t), \tag{25}$$

and substituting this result in equation (24), we find

$$M^t_{w,o'e}(t_t) = \gamma(1 + \beta_e)(1 - \beta_e) N^e_{w,oe}(t_t). \tag{26}$$

In the relativistic point of view, the same delay in time of the previous case, for the separation between O_{emb} and

O_{train} must be assumed, since for what matters there is always a delay in time for the receiver, when it means to observe what goes on outside the train. Independently of being approaching or departing, this delay only depends on the velocity.

Then, using the principle of conservation of information, we must have

$$M^t_{w,o'e}(t_t) = N^e_{w,oe}\left(\frac{t_t}{\gamma}\right) \tag{27}$$

As it was said before, the form of the equation is conserved, but the two observers are separated in time[21].

Using the fact that

$$N^e_{w,oe}(t) = N^e_{cy,oe}(t), \tag{28}$$

for any time, we can substitute these two last equations in equation (26), to arrive at

$$\gamma^2 = \frac{1}{(1 + \beta_e)(1 - \beta_e)}. \tag{29}$$

Substituting this expression in equation (17), we have the so called Lorentz transformation for times, in its fundamental form:

$$t_e = \frac{t_t}{\left(1 - \frac{v_e^2}{c_e^2}\right)^{\frac{1}{2}}}. \tag{30}$$

D. The Constancy of the Velocity of Light

Now, that we found the first Lorentz transformation, independently of the constancy of the velocity of the light, we can actually derive the constancy by calculating the velocities of approaching and leaving the train in the relativistic point of view.

As we assumed by principle, $observer - train$ is a classical observer and by this reason he cannot measure relativistic effects such as constancy of the velocity of the light. This constancy is only found when one calculates the velocities of the light approaching and leaving O_{train} in a mixed point of view. To complete the previous list of concepts of velocity of light, we must include the following concepts:

$c^r_{oe,ot}$ is the velocity of the light approaching O_{train} from O_{emb} with respect to the reference t_t.

$c^r_{oe,ot}$ is the velocity of the light reaching O'_{emb} from O_{train} with respect to the reference t_e.

We may start from the relation $c_e = c_t$, where the right side is the velocity of the wave emitted from O_{train}, with respect to O_{train}, in both points of view, including the classical view of $Observer - train$.

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[20] In *A mathematical Theory of Communication* [4], Shannon discusses the situation of two physical systems coupled by a pattern of waves, and what he assumes to be information. There he says that information is the number of messages, or any monotonic function of this number. By message, he means a physical specification. Applying to our situation, the event is the formation of cycles and this process is described by a numerical function, as he requires.

[21] This condition is not valid for material waves, only for light.

Consequently, we can assume that there is a λ_t such that

$$\frac{\lambda_e}{\lambda_t} = \frac{t_e}{t_t}, \tag{31}$$

holds. And substituting equation (30) in the last equation, we also find a relativistic correction between the wave lengths of these waves:

$$\lambda_e = \gamma \lambda_t \tag{32}$$

However, as said before, the velocity of the light approaching O_{train} must be calculated from a mixed point of view and a different correction holds for the approaching wave length.

Until now, only number of cycles were under the rules of relativity, according to the two relativistic principles. But if we assume that a wave is placed between O_{emb} and O_{train}, conditions must also hold for the wave lengths in between the same origins. Since there is an intrinsic time displacement due to the observational difference, thee must also be an intrinsic effect on the wavelength due to the displacement of the source. This corresponds to an intrinsic dilatation of the original wave-length. It has the contrary effect in this case, because it is the source O_{emb} which is relativistic displaced with respect to the reference O_{train}.

Substituting these results, the first velocity is given by

$$c_{oe,ot}^{r} = \frac{M_{w,ot}^{e}(t_e)(1+\beta_e)\lambda_e \gamma}{t_t} = c_e \tag{33}$$

where the coefficient $(1+\beta_e)$ of λ_e is the classical increase on the wave length because of the movement of the source away from O_{train} and the factor γ is the relativistic effect of length dilatation on the approaching wavelength.

And the second velocity only includes a relativistic correction for the wave length, of the other wave, the one leaving O_{train}, since the source is at rest. It is given by

$$c_{oe,ot}^{r} = \frac{N_{cy,ot}^{t}(t_e)(\lambda_e/\gamma)}{t_e} = c_e. \tag{34}$$

We finally derived the constancy of the velocity of the light, showing that it is a specific relativistic result only, not shared by any other point of view.

VI.   CONCLUSIONS

In our set-up we discriminate three classes of observers: observers of light represented by the equations of $observer - emb$; receivers of light represented by the equations of $observer - train$; and relativistic observers, represented by the unifying equations. The constancy of the velocity of the light is a relativistic result only. And the only one who observes the relativistic phenomena is the relativistic observer. But if the classical and the semi-classical observers do not exist, the relativistic observer disappears too. And the relativistic world vanishes with this being.

The train/embankment experiment is a prototype of relativistic phenomena not including interaction. The basic set up of the experiment of Michelson and Morley is the same situation. We can consider the same train carrying two mirrors, at equal distances from the origin O_{train} of our train. One mirror is localized on a line perpendicular to the velocity of the train while the other is in the direction of the movement. In this situation, light from the origin O' of the train is sent back and forth a great number of times from this origin, which moves with velocity v. According to the experiment, there is no difference in phase between the two perpendicular beams when they meet back in the origin.

In this experiment, the Earth corresponds to the train. Its tangential velocity corresponds to our v. The complete experiment is done under our single conventional Earth time, and we are the classical observers inside the train. Consequently, what the experiment confirms is that under its conditions, the classical limit holds. And, what is the classical limit? It is just the condition in which discrepancies in the velocity of light are not shown. Then, the first step to measure a discrepancy in the velocity of the light is by not taking its constancy for granted. But, in this case, we must find new ways to recognize, at remote distances, the objects of observation, because the constancy is just a theoretical tool for this.

In this paper we showed that because classical observers are receivers of light the velocity of light *in vacuum* is absolute. We did not show that classical observers exist as absolute beings.

VII.   ACKNOWLEDGMENTS

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Appendix: A model for physical observers

The purpose of this appendix is to discuss a model for physical observers borrowing elements from analytical psychology and philosophy. In doing so, we shall partly follow steps of physicists like Wolfgang Pauli, who introduced this psychology in the interpretation of classical physics, and mathematicians like Hermann Weyl, who concluded that the ultimate essence of the concept of the Ego is the system of reference.

Physicists usually consider observation identical to acquisition of data. This opinion has been rather disorienting, considering the level of antagonism still present in the literature in discussions about relativistic and quantum realities. Collection of data is not what observation is, although sets of discrete or continuous data can be considered elements of physical observations. A physical observation is an expression of a language made of observational concepts. [22] This language is made by sets of sentences such as equations, specifying the way these concepts are organized and related. In the simplest case, when the concepts are physical quantities, the relations are just associations between sets of data. The simplest examples of observation are equations of trajectories of moving particles.

But with sets of positions and measures of time alone one cannot arrive at these equations, because a trajectory involves a third element which is the movement of a body. It is the movement that settles the association and these trajectories are observed independently of the existence of any theory. Newtonian mechanics, which is a complete theory and does not only consist of observational expressions, was the first theory made for explaining these trajectories. Soon thereafter, new concepts emerged to describe global aspects of classical behavior of many bodies, in which the concept of trajectory does not play the main role. Observation of continuous distributions of matter such as fluids and waves produced other classical theories. From this point, physics developed in the direction of much more complex organization of data. Therefore it is very difficult to avoid the conclusion that physical observations are human acquisitions of language, where these languages are not the conventional ones but expressions of a collectivity, in the sense which we explain below.

To observe is also to think or have thoughts which can be linguistically expressed. Thoughts are complex formations of psychological elements existing and developing in

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[22] These observational concepts need not be physical quantities, but we will restrict ourselves to the case where they are.

intervals of time. This gives another meaning for a sentence of language, not as a fixed object made of signals, but as a constraint between elements during an interval of time. Consciousness has deep relations with language and therefore observers can also be considered from a psychological point of view, as conscious experiences, belonging to specific classes of conscious phenomena. Not only, physical observations must be understood as a special case of human expressions, in which all the subjective aspects of our existence are eliminated.

For these reasons, we take the term 'psychological' strictly from the Analytical Psychology, developed by Carl Gustav Jung and many collaborators, between them W. Pauli. This is the only psychological theory involved with a collective basis of the human thought [5]. In this theory, consciousness is a process made of functions such as thinking, intuition, feeling, sensation and perception. The totality of the conscious experience can have elements from many different functional sources, that means, descriptions involving sensations with feelings, between others.

Thinking is one of the functions of consciousness, the one which associates 'names' and 'meanings' to experiences. According to Jung there are two kinds of thinking: fantasy and language. This second kind of thinking can also include descriptions of subjective experiences involving sensation and emotions which are also experiences related to the body of the observer. But it can also be involved only with objective elements. The function named perception would be thinking of sensations and it can also include physical concepts. However, these experiences are always grounded on the spatial point of views of observers, what makes these reports subjective. This is not a feature of physical observations which are grounded on physical (objective) systems of reference. In our model we focus on 'physical thoughts', eliminating all the other functions, to relate to the equations representing the physical observations.

The main feature of analytical psychology, which is also a *sine qua non* condition for any model of observer in physics, is the fact that it assumes an archetypal or collective base for the consciousness and consequently for thinking. In the context of this psychology, certain manifestations of consciousness are not acquisitions of individual humans but of the psychic history of human kind. This makes a great difference between analytical psychology and all other psychologies, including psychoanalysis of Sigmund Freud. It postulates the existence of an autonomic psyche, without any influence from the individual consciousness, from which the conscious experience takes its deepest meanings. This psychic level does not consist of formed experiences but only of fundamental meanings or 'frames' for organizing them, the so called 'archetypal patterns'. And this permits the definition of objective experiences in a collective sense, only made by special concepts directly related to these patterns. This objectivity based on collective agreement is the main feature of physical observations. Actually, physical experiences are the most clear manifestations of a collective psyche.

Pauli [6] wrote about the influence of archetypal patterns on the ideas of Johannes Kepler and on the foundations of classical physics. And a deep connection between physical and psychological experiences was made by Weyl, who recognized the psychic nature of the physical system of reference [7]. He just identified our 'physical frames of reference' with 'components of the ego'. And the center of the consciousness, in analytical psychology, is the collective essence of the Ego, made mainly by the archetypal patterns (which are the psychological correlates of the innate ideas of Immanuel Kant [8] and of the intuitions of Luitzen Brouwer [9]). Considering only the patterns involved with physical experiences, we may use the expression 'physical ego' only for a sector of the ego as defined by Jung. This definition of physical ego, generating collective experiences, gives rise to experiences which could be interpreted as belonging to a collective consciousness. The existence of the latter can be considered as paradoxical, and was firstly rejected by Jung. But during his life, Jung refined several times the concept of ego [10], reaching this final conception in which the ego is a collective and structural base for experiences.

The concept of physical ego, as adopted here, means a class of physical references, as building blocks of physical experiences and consequently of the physical world. Each class may consist of infinite systems of the same references. And different classes consist of different sets of references. For Weyl, there could be no objective experience detached from the ego. "The objectization, by elimination of the ego ... does not fully succeed, and the coordinate system remains ..." [7] We can assume here that system of coordinate is used meaning system of reference. This idea of Weyl makes it also possible to differentiate between classes of physical observers based on different classes of references. A class of references forms a closed structure in itself, classifying physical experiences and observational language as well. Here the term 'world' accounts for the infinite set of all possible descriptions by a class of observers.

The idea of Weyl, also permits to understand the relation between the different classes of observers from a different perspective. The concept of complex, introduced by Jung and collaborators, is the key for this analysis. A complex can be defined as a set of experiences limited by a specific ego. Comparing to our case, a complex would be represented by a set of observations corresponding, not to different observers from the same class, but to a specific class of observers. In Newtonian physics, for example, these references only consist of the set of real numbers, three spacial axis, time and movement. With these fundamental ingredients, the classical world is formed. This would be the classical complex. With special relativity a new reference emerges, that is light, resulting in a deep change of reality. These new experiences, belonging to a new integrative complex, consist of the observations of another kind of observer, named the

relativistic observer, see Section V.

The main issue of the present paper has been to point at different kinds of observers, coexisting inside the final experience. The situation actually resembles human psychology and integration of personalities. It is well known that human personalities can be broken in psychological complexes. Complexes have great importance in the understanding of consciousness. As practically independent psyches, their split accounts for situations such as double consciousness and schizophrenia. And, in principle, conditions like this can be cured, by means of a reintegration of the parts. It can also happen by means of the emergence of a third entity, giving an unity for them. This would be considered as a cure of the pathological situation.

Here, the situation resembles these psychological situations, but cannot be considered the same in the sense that we are not discussing processes of individual minds. These complexes would not be human personalities but some sort of 'collective manifestation'. Moreover, it is not under a unique time that happens their integration. Our third observer, is not to be thought to represent experiences based on a third reference of time or give a special status for one of the references of time. It keeps two times as an integral feature of the experience.

A previous inventory of the plural observation inside special relativity, was carried out by Bruno Latour [11]. It is very interesting to realize that the original duplicity of languages of special relativity with the realization of an integration, needing a 'personification', is clear from very different perspectives. In both approaches, the existence of special relativistic events, objective or not, only can be meaningful with respect to a third observer. More recently, an analysis of observational discrepancies in Einstein's exposition of the train/embankment experiment, was made by Avi Nelson [12], and discussed by other authors [13]. Nelson also considered the possibility of an observational plurality but kept the notion of observation attached to sensation and perception, in the way Einstein did. An integration between observers leading to a third observer is not possible in these terms.

This is mainly because sensation and consequently perception are not processes of a collectivity but of individual organisms. Physical observations have an unique status and cannot even be assumed to be neuro psychological, if we had to consider each of us individually as observers. Since the brain, considered as the set of neuro activity, is a physical object in space and time, it becomes very difficult, and even a nonsense, to trace processes inside it, which could account for the objectivity of the space outside, as an individual experience. But, considering the geometrical aspect of the experience of space only, another context for the mind-body question emerges. Models for neural correlates of consciousness (NCC) involve processes of neural integration, considering single brains [14, 15, 16, 17]. There is no successful model till now although evidences of neural processes mediating psychophysical processes have been found. If the neurological brains are just big complexes of interconnected neural systems, it is natural to think that integrations could also happen interconnecting different brains. As far as we know, this kind of parallelism has not yet been discussed as a possibility. But this type of speculation is out of the scope of the present paper.

Another crucial contribution for this model of observer adopted here, comes from the philosopher Rudolf Carnap [18], who stressed the linguistic nature of physical observations. For him, physical observations form 'worlds of languages' by producing specific languages. These so called observational languages ought to be detached from the theoretical languages, inside specific theories. But the propose of Carnap apparently failed in practical terms because of the difficulty to find general criteria for separating observational concepts from the theoretical ones. He was the first to recognize this fact, pointing to the divergences of opinion on this matter.

For finding the observational languages we need two criteria. The first is to separate observational terms inside a specific theory differentiating observational and theoretical languages. We adopt a historical guidance and simply postulate the primary references from an analysis of Newtonian trajectories. Then we separate from the observational language all statements with concepts not built exclusively by these primary references. The second criterion is to define different theories by means of recognizing different observational languages. This can be done by assuming that a change in the number of primary references, not considering changes in the physical meaning of the references, means a different observational language.

From an integration of these ideas we conclude that to observe is to describe, focusing our analysis on the equations. The description is a kind of organization of the reality. An observer is represented or manifested by the report, not by the body of a person. For this reason, observations do not depend on the position of persons (bodies of persons) neither observers have physical influence on the world. Another aspect of observers and of these archetypal references here discussed is that these references are not choices from human beings. According to analytical psychology, the unconsciousness has its own dynamics, independent from the consciousness. The development of the ego, considering its collective essence, is not under the domain of consciousness. In this specific aspect, the development of knowledge does not obey our will.

The question of the nature of the psyche, whether it is a metaphysical entity and whether observers only can be human, [23] deserves careful discussions but it can be

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[23]

If history had developed differently by not having the world dominated by us, homo sapiens-sapiens, it might have been necessary to question whether Neanderthals and Homo Erectus could have served as good 'observers' in the sense discussed here. In real-

avoided here, at the expense of understanding that language, as strongly emphasized by Karl Popper [19], has an objective feature, which is independent of single human physical existences. Although being a product of human culture, it is made outside individuals. For this reason, in case of physical languages, observational information can be conveyed by instruments (but it is not to be misunderstood as being the instrument) independently of a physical presence of a specific person to read it. The only difference introduced here from analytical psychology is in the collective or archetypal nature of the observational concepts, with respect to the human ob-

ity, there remains this question about the more clear cut case chimpanzees and other great apes. Though the answer seems that they are not 'good observers' of the type we discussed, un-

server, which contrasts with the opinion of Popper. This contrast is more related to the way in which we know and understand these concepts, whether from experimentation or not. But this is a very old philosophical discussion which we also do not need to enter. We just take for grant that these physical concepts of space and time have a collective meaning, that they do not belong to specific cultures but to the totality of the human kind. Lastly, we assume that for the situations discussed here, these observations consist of continuous associations between these concepts, what cannot be made by instruments or machines.

derstanding of their language would be of great help to reach a definite conclusion.